Simulations During Operations

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SIMULATION TECHNOLOGIES can simplify commander and staff responsibilities during operations. Traditionally, the Department of Defense (DOD) has focused on analysis and training simulations, and no operationally focused simulations (OpSims) specifically support operations. Simulations designed for course-of-action (COA) development and analysis, rehearsals and operations monitoring will make staffs and commanders more effective.

The Army Modeling and Simulation Office (AMSO) recognized the importance of simulation in command and control and identified five voids in current modeling and simulation technology for the Army After Next.[1] Three of the voids are automated decision aids, COA tools and tactical information aids. The methodology proposed in the *Proceedings of the 1998 IEEE Information Technology Conference* will fill these three technology voids.[2] The Defense Advanced Research Projects Agency (DARPA) has also recognized simulation's importance in command and control activities. A DARPA concept briefing for the command post of the future project provides a list of several tools that will provide input to the battlespace-reasoning manager. Among these are planning and analysis applications and three-dimensional models and simulations. The DARPA briefing also notes that "battlespace reasoning, analysis and simulation" help the commander perceive and understand battlespace.[3] Finally, Robert J. Bunker describes one form of information to gather and protect during information operations as behavior information, the "three-dimensional simulation that will predict the behavior of at least physical objects, ultimately being able to 'wargame' courses of action."[4] Despite wide recognition of simulation's eventual usefulness, there seems to be no methodology for exploiting it.

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Carl von Clausewitz discusses the "feel of the battlefield" and how great commanders deal with friction and see through the fog of war.[5] He also notes that this feel only comes with experience. Unfortunately, this experience costs human lives. The Army developed facilities that attempt to build this experience at relatively low cost, including combat training centers (CTCs) and training simulations such as Corps Battlefield Simulator (CBS), Brigade/Battalion Battle Simulation (BBS), Janus, Joint Tactical Simulation (JTS) and Warfighter Simulation (WARSIM) 2000.[6] With severely constrained budgets and 100-hour wars, the Army has limited means to identify those officers who have this feel of the battlefield. The simulation methodology described in this article provides a means to augment the commander and staff's battlefield expertise.

Operational Simulations

OpSims leverage simulation technology to improve situational understanding, prevent information overload and keep the commander inside the enemy's decision cycle. Armywide efforts to improve situational understanding are under way. An OpSim enables the commander to analyze past events, observe current operations or predict the future. An OpSim provides more than just a view of the battle; it analyzes the implications of friendly and enemy decisions in real time. An OpSim, like a computer chess analyzer, simulates COAs into the future and provides timely, accurate information so the commander can make timely, proper decisions.

An OpSim will improve situational understanding by preventing information overload. Using multiple digitized tools can give commanders more information than they can process.[7] OpSims, as part of a larger system, draw attention to aspects of the current operation that could lead to failure. This helps the commander and staff focus on important information and screen out unimportant data. Ultimately, the commander's decision cycle will be faster than the enemy's.[8]

Simulation Uses During Operations

Conducting military operations generally consists of planning, rehearsal, execution and after-action review. These are not distinct phases but usually are concurrent and continuous actions. However, it is helpful for discussion to treat each action as a distinct phase and consider the effects of simulation technology during each.

Planning. During the planning phase, staffs develop COAs. The current method involves staff members discussing the COAs.[9] Each phase of the operation is analyzed according to an action-reaction-counteraction paradigm. This ad hoc method has numerous problems. The effectiveness of the war-gaming process depends on the skill of the commander and staff members. It is doubtful that many planning staffs have the feel of the battlefield that Clausewitz describes. Numerous time and space relationships must be considered when conducting the action-reaction-counteraction analysis, and no tools exist to help staff members. The effectiveness of an action-reaction-counteraction COA analysis also depends on the planning staff's interaction. In reality, staffs rarely have time to coalesce. Except for lock-ins and ramp-ups for deployments to large-scale training exercises, personnel rotations ensure that some planners will be new.[10]

Finally, the same officers who develop the COAs are the ones who analyze them for strengths and weaknesses and determine the criteria used to evaluate the COAs. Despite their best intentions, the planning staff carries personal biases toward the COAs. Using developers as evaluators can lead to groupthink.[11] Given a bias toward one COA, it is easy to manipulate the criteria, evaluation weights and

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decision-support matrix to support the preordained choice. Whether conscious or unconscious, bias is a risk of this ad hoc procedure. In the current planning process, once the formal decision briefing to the commander commences, it is unlikely that the staff will openly oppose the COA recommendation. Normally, only a forceful commander, assistant deputy commander or chief of staff can counter such group-think.

OpSims provide powerful new tools to the planning process, allowing staffs to simulate and assess enemy and friendly COAs. The staff and commander can then use the simulation results to evaluate the plan and choose a COA. Using simulations will highlight problems (especially synchronization issues), produce higher granularity and provide better feedback for a timely, more accurate COA assessment.

Simulations are no panacea. The parameters used to initialize the simulation can be biased, and the attrition model can be inaccurate.[12] The staff can still propose "straw-man" plans. Given these potential pitfalls, however, OpSims would still provide a more accurate, rigorous assessment of COAs than the current manual process. Also, the proposed system's adaptive nature will help ensure that the simulation's parameters will be more real.

A staff usually proposes two valid COAs and one "throwaway" because the commander normally wants three choices, and the staff usually lacks time to analyze three COAs adequately. Staffs will be able to analyze more viable COAs with a valid simulation.[13] The manual method worked in an industrial-age Army, but it is no longer appropriate for an information-age Army that needs to stay inside the enemy's decision cycle.

A simulation-based process also allows the commander to conduct experiments in parallel with the planning staff. One OpSim requirement is that a single user can operate it on a single workstation. The commander can experiment with one or more COAs, personally conducting mission and COA analysis while the planning staff works on the same ones or others.

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If time permits during military operations, the planning staff explores possible alternative actions during the operation (branches) and follow-on operations (sequels). Simulating the plan makes it faster and easier for the commander and planning staff to explore more branches and sequels in detail. The current procedure allows little time to analyze branches and sequels, so only the most likely, and maybe the most dangerous, branches and sequels can be explored—often superficially.

Having the OpSim at multiple echelons will speed the planning cycle. Once a division headquarters has completed the plan, it can transmit the plan file electronically to each of its subordinate brigades. The brigade planning staff can then cull out entities that are unlikely to affect them, partially disaggregate the entities in the division plan to be appropriate at brigade level and begin to flesh out the brigade plan. Our forces can stay inside the enemy's decision cycle if lower-level headquarters spend less time copying overlays and redrawing plans and more time conducting mission and COA analysis. The planning cycle can be compressed without degrading the effectiveness of the process.

Rehearsal. Once a COA is chosen, a full plan is developed and rehearsed. The simulation will facilitate this detailed rehearsal. Certain rehearsals—such as fire support; close air support; nuclear, biological and chemical support; and mobility/countermobility/survivability—are difficult to conduct using sand tables and maps. Clearly, simulation would improve these types of rehearsals; however, a simulation-based rehearsal would be useful for the traditional, maneuver-centric rehearsal. Rehearsals identify synchronization issues and make sure that everyone fully understands the plan. A simulation that could be halted at any time would benefit rehearsals just as large sand tables and map boards do today.

A significant advantage of a simulation-based rehearsal is that, potentially, it could be distributed geographically. With a number of distributed graphical interfaces to the same simulation, the commander and operations officer could play back the plan while the subordinate commanders and staff members watched from remote locations. The rehearsal could be conducted without all the key players getting within grenade-burst radius of each other.

Execution. After the plan has been chosen, refined and rehearsed, and the operation commences, the proposed methodology can be used to monitor the progress of the simulated plan and the real operation. Intelligent software agents, referred to as operations monitors (OMs), compare the real plan's progress against its simulation. When significant deviations from the plan occur, the OMs launch tools that explore the impact of these deviations. Finally, the commander is advised if the OMs determine that the plan's success is in jeopardy.

After-action reviews. After-action reviews are important—even during a war. The course of the real operation could be recorded and archived for later review. As time permits, the operation can be played back for key leaders, allowing them to identify synchronization problems or other errors. During training exercises, observer/controllers often monitor the operational planning and execution and provide feedback. This capability is not likely during real operations, but using an OpSim could help fill this void.

Unsuitability of Training Simulations

The military community has developed a large number of simulations, such as the CBS, BBS and Janus, for training and analysis. Many of these excellent products are unsuitable for use during an operation—extensive pre-exercise preparation, specialized hardware, large numbers of required participants and large numbers of required workstations. Using an OpSim during operations requires specific capabilities:

- A single user must run the simulation from a single workstation. During ongoing operations, op-

US Army

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erations centers are crowded, bandwidth is limited and contractor support is limited. A simulation that cannot be run by a single person on a single workstation would represent a significant burden to an already busy staff.

- The simulation must run in low-cost, open-system, multiplatform environments. While this proposed methodology concentrates on military applications, an OpSim is also well-suited for activities such as emergency management, disaster relief and fighting forest fires. Often, the local police and fire units tasked with handling these types of emergencies only have low-end hardware.
- The simulation must be run in multiples of clock time (real time and faster). The simulation should be able to run very fast during planning and rehearsals and run in near real time during operations.
- The simulation must be able to receive and answer queries from external agents. This ability allows external software agents to use OpSim to monitor the current operation for deviations from the plan.
- If needed, multiple simulations should be able to operate together. While there is no immediate need for multiple, cooperating simulations, this simulation should comply with known, accepted protocols so this ability is not precluded if it is needed.
- The simulation should be built on an aggregate-level model. In military operations, commanders think two levels down and fight one level down. This level of abstraction is sufficient for the simulation users; therefore, to run much faster than real time, the simulation need not be entity-level.[14]

A prototype simulation implementation that meets these requirements uses a VMap-2 terrain database

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that addresses the issue of exercise setup time and cost.[15] This methodology does not rely on the simulation developed; any simulation that meets the requirements could support this proposed methodology for using simulations during operations. The government-developed simulation, Modular Semi-Automated Forces (MODSAF), does not have all the properties described but may be appropriately modified.[16] While MODSAF and its proposed follow-on product, OneSAF, are entity-level simulations, their distributed interactive simulation and persistent object protocol could be wrapped in an "agent" to receive subscriptions and answer queries.

Proposed Methodology

The proposed methodology involves the interactions of a number of packages and tools, including the OpSim, intelligent agents, combat-attrition models and path-planning algorithms.[17]

Operations monitors (OMs). The OMs are the heart of this methodology. They take information from the real world and update entities in the simulated world, seamlessly resynchronizing the simulation to the real world. More important, they monitor the simulation's progress and compare it with the real operation's. When they discover significant deviations between the real world and the simulated world, they launch one of many tools to analyze the deviations. OMs do not act on the plan; they explore the ramifications of the differences between the real operation and planned operation. OMs help manage information by making judgments on the impact of any differences and issuing advisories, but they should be considered part of the team, not a replacement for commanders.[18]

OMs also must be proactive. It is not sufficient for an OM to inform commanders of a broken planning timetable. They do not provide just data; they analyze and synthesize data to provide relevant, timely information. OMs must look ahead and inform commanders if some goal is not likely to be met. For instance, if some future event requires three of five preconditions to be met, the OM must determine whether these preconditions are likely and assess the probability that the goal can be accomplished. When this probability becomes low enough, the OM must inform the commander.

WorldView. The WorldView module represents the real-world operation. To make the OMs' job easier, the representation of the state of the real operation and the simulated plan should be as similar as possible. WorldView receives information about the state of the real operation through a series of application program integrators and transforms the information into a form the OMs can easily interpret.

WorldIntegrator. WorldIntegrator monitors the real operation, processes information and passes it to WorldView. In some systems, such as the Global Command and Control System (GCCS) or Army Battle Command System (ABCS), this may involve querying a database. In other systems, this may require eavesdropping on the network. This intermediate step is required in real operations because reports

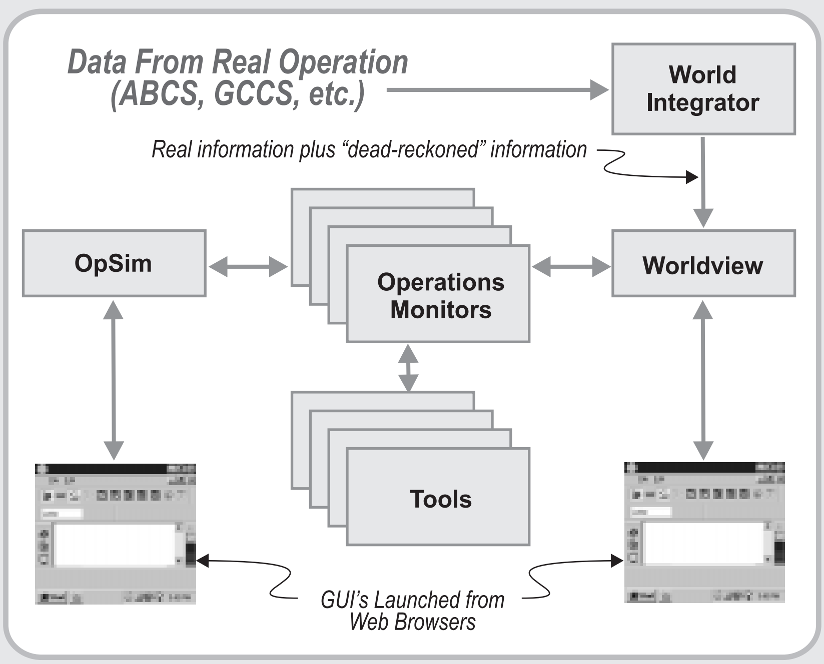

Figure 1. Proposed Methodology

on some entities may be intermittent. WorldIntegrator must "dead reckon" these intermittent reports and pass them to WorldView. When an entity has been dead reckoned, this must be reflected in the information that WorldView gives to the OMs.

WorldIntegrator and WorldView involve sensor, data and information fusion. WorldIntegrator must determine when an entity has been unconfirmed long enough that its actions must be dead reckoned. When some sensor reports a similar unit, WorldIntegrator must determine whether it is the lost unit reappearing or a different unit. These and other sensor, data and information-fusion issues require further research.

Normally, OMs do not make tactical decisions; they explore differences and report findings. The OMs have autonomy to decide when to launch other tools. As noted in DARPA's command post of the future concept, battlefield visualization tools should be decision centered and "show decision-relevant details, highlight relevant changes, anomalies, [and] exceptions and portray uncertainties."[19] These are exactly the pieces of information that our proposed methodology provides. Visualization is not a tool to present the battlefield in a unique way; visualization occurs within the heads of the commander and his staff.[20] This proposed methodology provides additional support for that process.

Synchronizing the Real Operation With the Simulated Operation

If OMs are to compare adequately the real operation with the simulated operation, the two representations must be close. An axiom in military planning is that no plan survives the first rifle shot. Once the operation commences, the plan will certainly diverge from the real operation. OMs must identify when this divergence has become so great that the operation's success is in jeopardy and report these concerns to the decision maker.

Once the commander is notified that the current simulation no longer accurately reflects the state of the actual operation, the simulation should be updated. If the simulated plan continues to diverge from the real operation, over time, they will become almost completely unrelated. Any analysis the OMs would perform at that point would be meaningless. This updating also allows OpSim to predict better where the operation will be in the future. The problem, however, is to define a synchronization mechanism that is feasible and adaptive.

The combat effectiveness of entities (units) in the simulation is characterized by some probability distribution(s), such as the well-known normal distribution (or bell curve). These probability distributions (which may be different for different classes of entities) are used to analyze the various COAs during the planning phase and simulate the interactions among the entities as the simulation parallels the operation in near real time.

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When OMs determine that the real operation and the planned operation are significantly different, they have historical data on those entities' actual effectiveness. The OMs must do two things: update the current state (such as the number of casualties, number of vehicle losses, number of key weapons lost) and update the entities' future performance within the simulation. An OM tries to refit the historical data to the family of probability distribution described for that class of entity.

Another, less-technically interesting, update of OpSim would occur when the number of entities was significantly different. For example, if the plan assumed the enemy would have three tank battalions but WorldView indicated the enemy actually had four, OpSim would need to include this additional unit in the future. Adding this unit automatically would be difficult since an intelligence officer would have to provide OpSim with an estimated plan for this new entity.

The basic idea, therefore, is for one or more OMs to compare the simulation's performance with the real operation's. The OMs can make small updates in OpSim's parameters automatically. For larger deviations, they query the users for help. The amount of data that needs to be gathered before the differences are significant is unclear. One problem with analyzing military operations is that the experiments are not reproducible: much of the area of operations is destroyed in the process, and many of the witnesses are killed. One approach to dealing with this issue is for the threshold (used to determine whether to update automatically) to be adaptive. The OMs

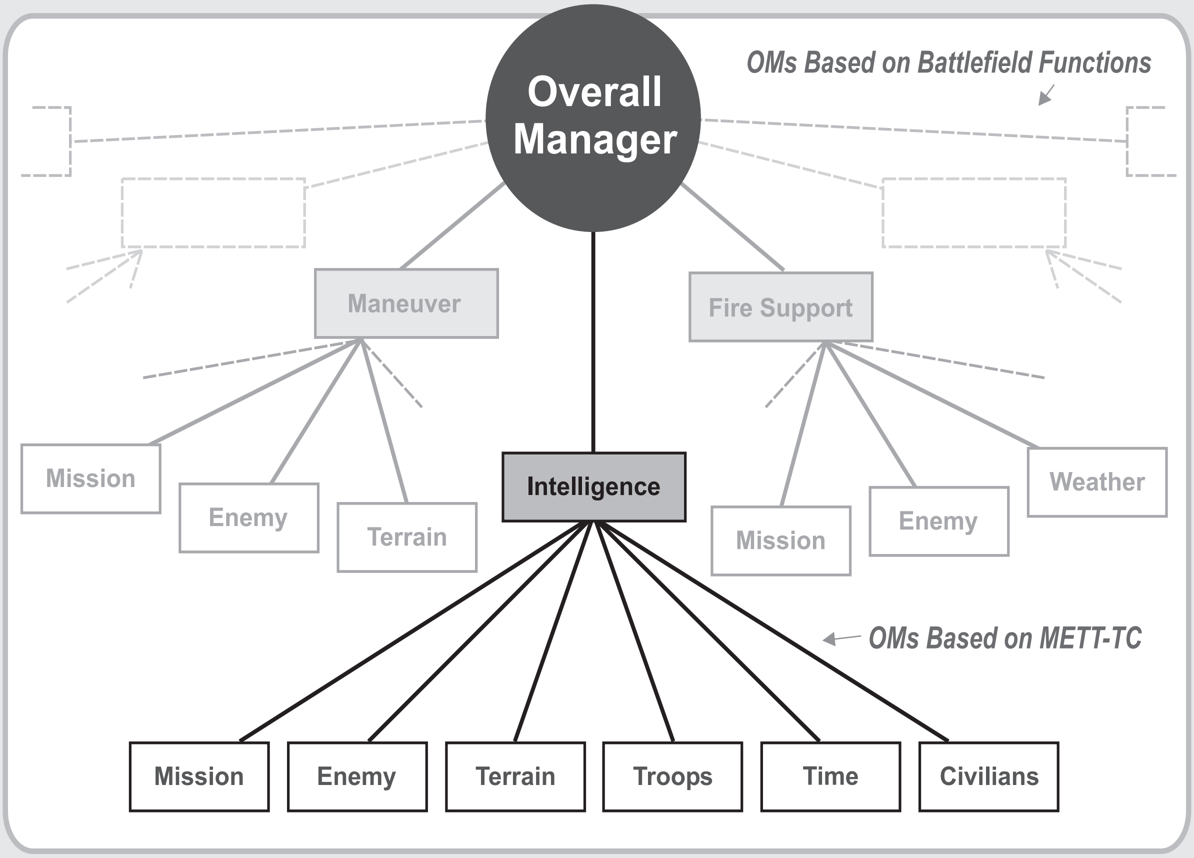

Figure 2. A Possible, Partially Expanded Hierarchy OM

can use the performance of the simulation after an update to help it adjust the threshold.

As stated earlier, OMs focus on a narrow domain to make their design and implementation more tractable. When the system is first launched, a manager OM creates the first layer of OMs in the hierarchy. The overall manager synthesizes the reports of the agents below him in the hierarchy. The first layer of OMs compares the current situation with the plan, each looking at the operation from a particular, narrow perspective. One such taxonomy for OMs in this layer is using the combat functions defined in US Army Field Manual 100-5, *Operations*: intelligence; maneuver; fire support; air defense; mobility and survivability; logistics; and battle command.[21]

The OMs in the first level have several tools (and additional agents) available to help them perform their analyses. One possible taxonomy for agents in a second OM layer might be using the Army's mission, enemy, terrain, troops, time available and civilians (METT-TC). Under this taxonomy, one OM would look for differences in the enemy's size, strength, and composition. Another might be looking at terrain and weather effects.

Future Work

A prototype OpSim allows OMs to subscribe to information.[22] It is an aggregate-level, discrete event simulation capable of near-real-time and faster operations.

This prototype allows plans to be created for various light and mechanized platoons and companies, both friendly and enemy. Cloning and modifying the first plan eases the process of inputting several plans and aids in exploring branches and sequels. Once all plans are created, a number of simulation experiments (runs) can be conducted. Finally, the user receives a table that describes the average number of personnel, vehicles and weapon systems lost during each experiment. This feedback gives planners one criterion in the decision matrix for choosing a COA. OpSim can also be run in near real time, along with a real operation. In addition to creating the OMs, future work on OpSim includes:

- Improving the simulation's query-response capability and permitting one-time queries in addition to subscriptions.
- Creating OpSim's ability to run different plans at different speeds so that it could run the current

operation in near real time while running the plan (or a branch or sequel) as fast as possible to predict its outcome. This would also allow planning the next operation to be interleaved with monitoring the current one rather than treating them as time-ordered, separate processes.

- Improving the simulation's statistics-gathering and reporting capabilities.
- Improving OpSim's ability to get information from the terrain database.
- Improving the application program integrator.
- Making the simulation comply with various DOD protocols. As an aggregate-level simulation, it should comply with a protocol like the DOD Aggregate-Level Simulation Protocol (ALSP), and the intent is that it eventually will.[23]
- Making the overall system recognize more than just quantifiable aspects of an operation. The overall methodology must eventually be able to assess a plan's effectiveness based on attributes other than just numbers of soldiers and systems lost.

The ability for agents to query the simulation is vitally important to implementing this proposed methodology; consequently, this capability is receiving special emphasis. A number of possible methods are being explored.

The OMs can make small updates in OpSim's parameters automatically. For larger deviations, they query the users for help. The amount of data that needs to be gathered before the differences are significant is unclear. One problem with analyzing military operations is that the experiments are not reproducible: much of the area of operations is destroyed in the process, and many of the witnesses are killed.

This article proposes a methodology using an OpSim that runs in real time and simulates the plan. The simulation uses intelligent agents—OMs—to compare the events in the real operation with those in the plan. The OMs query the real operation's representation and the simulation to determine deviations and launch various tools to learn the effects of those deviations so they can advise the commander and staff if the effects are significant. OpSims, as the center of the proposed methodology, are important to an information-age army seeking to improve its situational understanding, prevent information overload and help commanders stay inside the enemy's decision cycle.

NOTES

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9. US Army Student Text 100-9, *Staff Operations* (Fort Leavenworth, KS: US Army Command and General Staff College, 1996).
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11. P. Wyden. *The Bay of Pigs* (New York, NY: Simon and Schuster, 1979).
12. The current simulation implementation allows analysts to replace the attrition model with any other valid model.
13. The use of valid is in the nontechnical sense. It may not even be possible to fully validate *any* combat simulation.
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15. VPF and VMap-2 are registered trademarks of the National Imagery and Mapping Agency.
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